

Living Laboratories

Creating 'Smart Buildings'

What if your house were a mini-power plant, generating the power you need to live? Imagine—solar panels in the form of roof shingles, heat-collecting walls, and fuel cells powering your appliances, heating your home, and even charging your car. And buildings of the future will be “smarter,” with windows that automatically darken to shade during

the heat of summer and open or close to allow natural ventilation. Computer systems will automatically control lighting levels and turn on and off your appliances. All of these technologies and concepts will make the buildings of the future more productive and comfortable, extremely energy efficient, and secure—continuing to run even if the electric grid is down.

Living Laboratories

We might be further along the path to this future than you realize. Researchers are testing home and office designs today that are up to 80% more energy efficient than those built when NREL first began operating. These new building designs combine renewable and energy-efficient technologies in ways we could not have imagined in past decades.

In fact, much of the focus in improving buildings today is taking knowledge gained in past research into the real world to test it there. These real-world test sites, or living laborato-

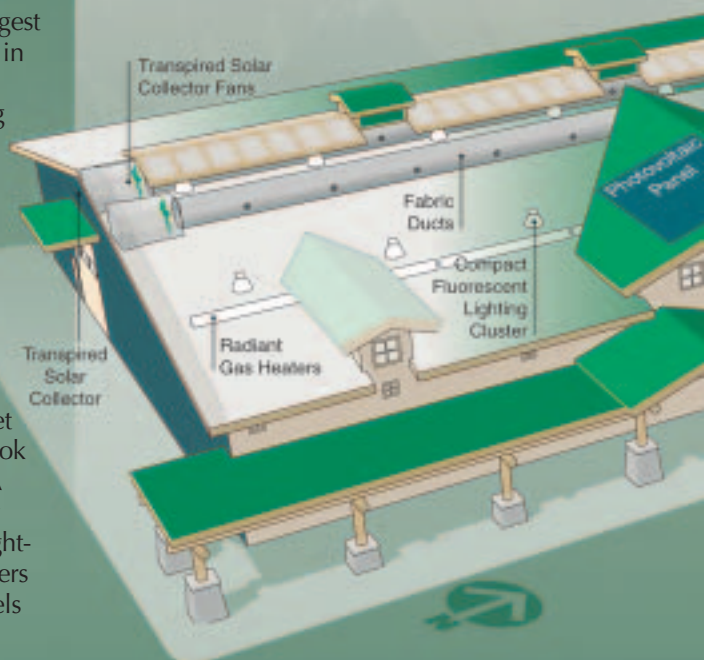
Shopping Mile High

Even high in the Colorado mountains, where winter temperatures cause heating challenges for any building, BigHorn's large, retail spaces and warehouse are consuming 62% less energy than a similar, conventional space. NREL's researchers helped to design and test, and continue to monitor the complex, which is

breaking ground for the future of retail space with a lot of “firsts.” The complex is one of the first retail buildings in the United States to use daylighting and natural ventilation cooling systems, the largest commercial photovoltaic array in Colorado (9-kW capacity), the state's first commercial building to have a standing-seam, roof-integrated PV system, and the first retail center in Colorado to have a net metering agreement (where electricity produced over the amount used is sold back to the utility). Inside the building, customers experience radiant floor heating, and large, operable windows that let in Colorado's bright sun and look out on the Rocky Mountains. A computer system automatically balances the ventilation and lighting levels to make sure customers have the optimum comfort levels for shopping.



The BigHorn high-performance building features PV, clerestory windows, daylighting, diffusing skylights, and solar wall. Anticipated energy cost savings from all the features, not including PV, is 62%.



ries, use technologies and research results from industry (as well as from laboratories) and look at them as a whole system—testing how all the separate pieces are functioning together. More important, living laboratories show how the various systems in the whole building can be more efficient and cost effective.

NREL's work in both the commercial building sector—schools, office buildings, and retail buildings—and the residential sector—single family homes, apartment buildings, and housing communities—helps move both markets forward by acting as a way for manufacturers, builders, and designers to find out how their products and technologies can be more effective.

Changing the Way We Work and Shop

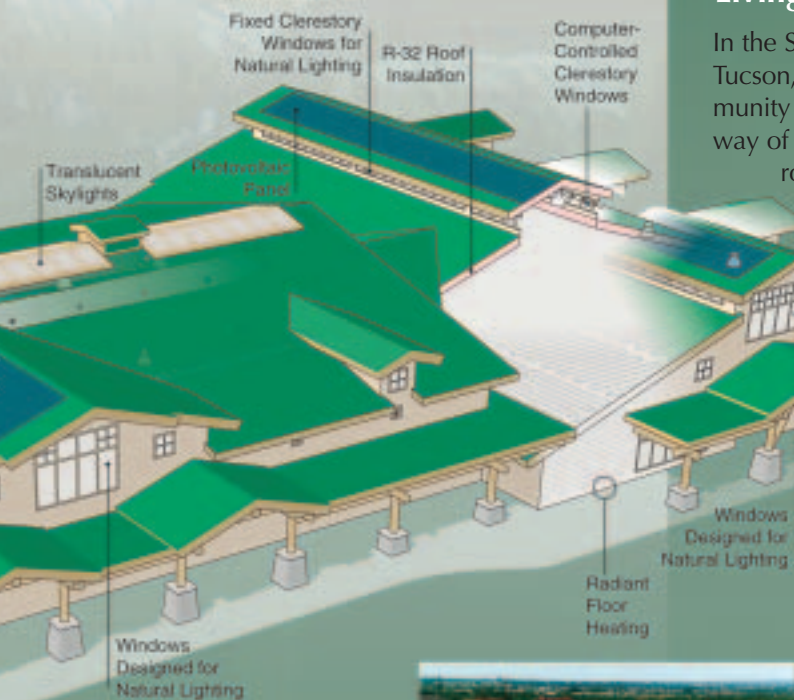
In the mountains of Colorado, the BigHorn Retail Complex in Silverthorne is one of the nation's first retail buildings to use natural daylight and ventilation cooling. The complex is designed to allow light into the building without creating too much heat, and because of careful design, no air-conditioning system is needed. A photovoltaic system integrated into the roof, along with energy-efficient features like a solar mass wall and compact fluorescent light fixtures, has reduced energy use by more than 60%.

BigHorn is one of many living laboratories testing the most advanced building technologies in the world. "Scientists have spent the last two decades measuring energy in buildings and finding out which technologies, by themselves, are most efficient," says High-Performance Buildings Task Leader Paul Torcellini. "Now," he says, "it's time to design a decision-making process to consider all the parts as a system."

"Designing efficient buildings is a process—based on hard science—that helps us build commercial buildings that are more environmentally sensitive and comfortable," Torcellini says. "In this stage of research, we're trying to weigh the benefits of different building features, instead of just testing windows or photovoltaic systems."

Changing the Way We Learn

In addition to being a living laboratory, where researchers hone energy efficiency and design technologies, Oberlin College's Center for Environmental Studies is a living classroom for students, where the building itself is the main topic of study. The building's wastewater is treated using a system of microbes, plants, snails, and insects. A solar electric system on the main south-



The pool of the Civano development in Tucson, Arizona, uses a 6-kW photovoltaic installation to help meet the community's energy standard.



Living Desert Wise

In the Sonoran Desert around Tucson, Arizona, the Civano community members are trying a new way of coexisting with the environment and each other. The 820-acre neighborhood development was designed to promote economic growth while focusing on social values and ecological harmony. The community supports housing, as well as light industry and commercial and retail businesses located no more than a 5-minute walk from the homes. Another goal of the community is to minimize the use of natural resources substantially below pre-



Each home at the Civano development incorporates results of systems engineering developed by teams under the Building America program.

vailing levels in comparable developments, in part by using renewable energy and creating building designs that are energy efficient—all the homes in Civano use less than 50% of the energy of a conventionally built home and all have solar water heaters. NREL's researchers have been monitoring the efficiency of Civano's homes, collecting data and creating virtual models of the buildings on computer to understand how energy is being used and how to improve performance.

facing curved roof provides half of the electrical energy for the building. Overhanging eaves and trusses shade the summer sun while allowing winter heat gain. Natural light comes into the building through clerestories and south-facing windows, reducing the need for electrical lighting.

At the center, electronic sensors track light intensity, electricity produced by the solar electric panels, and energy consumed by the heating and ventilation systems. A monitoring system helps students and NREL researchers understand how a building interacts with its environment and how it behaves as a system.

In many schools, students and researchers alike learn about energy efficiency and renewable technologies through partnerships—like the one with Oberlin—and programs like DOE's EnergySmart Schools. NREL's EnergySmart Schools Coordinator Patricia Plympton says that these programs are transitioning our schools to new ways of using and teaching about energy. "Sometimes students can teach us how to make classrooms more comfortable and productive using energy efficiency and renewable technologies," she says. "We're all learning from these living laboratories."

Changing the Way We Live

In the desert community of Civano, outside Tucson, Arizona, all homes use 50% less energy

than a traditional home. The sun is used to heat water for swimming pools and homes, and photovoltaics help to offset electricity consumption. A network of bike and walking paths connect office buildings with homes to reduce the need for driving. Native landscaping and efficient building materials help the community live within the desert ecosystem, reducing water consumption and the need for air-conditioning.

Research on communities like Civano is helping scientists measure the effectiveness of technologies and improve designs. Energy performance is monitored and put into a computer system to model ways to make the homes even more efficient. This huge network of living laboratories is a catalyst for change in the home-building industry. Many large builders are starting to see the benefits of producing homes on a community scale that use 30% to 50% less energy, reduce construction time and waste by as much as 50%, and provide new product opportunities to manufacturers.

"We work with builders and designers, who are changing the way homes are built," said Paul Norton, NREL project manager for DOE's Building America program. "Our

Competing for the Future

For eight days in 2002, 14 student teams will participate in a competition that will be a living laboratory for future designers, engineers, researchers, and communicators. The student teams will compete to capture, convert, store, and use enough solar energy to power a "home" they will build themselves



The 2002 Solar Decathlon team from the University of Colorado at Boulder developed the design of their house in a collaborative effort between engineering and architecture students.

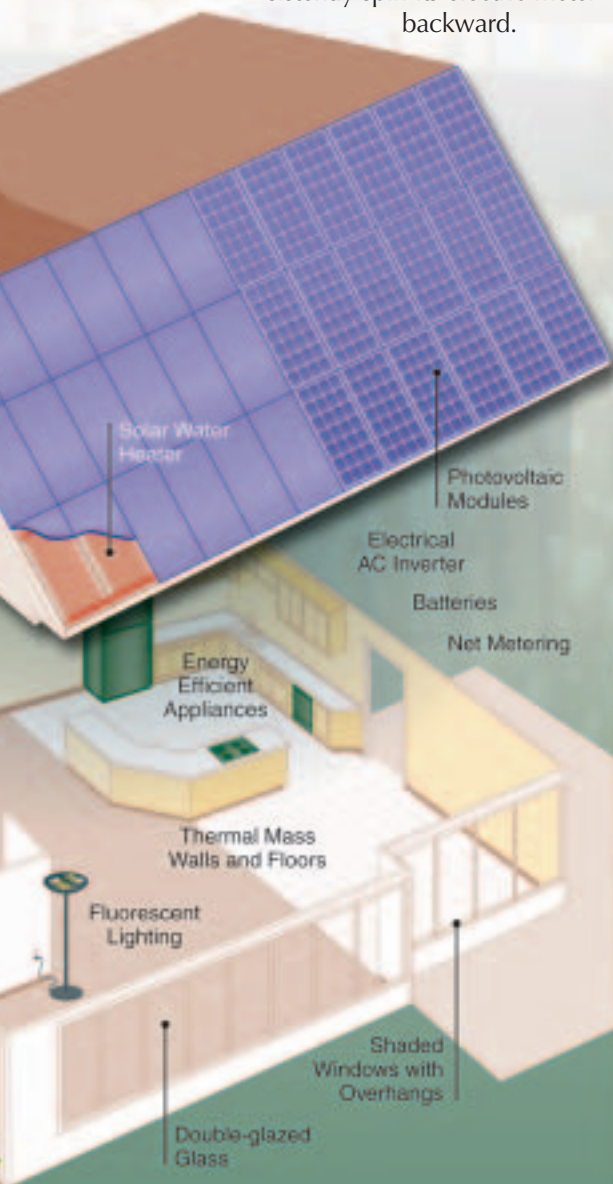
on the Washington, DC, mall. Solar Decathletes will be required to provide all the energy for an entire household, including a home-based business and the transportation needs of the household and business. During the event, only the solar energy available within the perimeter of each house may be used to generate the power needed to compete in the ten Solar Decathlon contests. The Solar Decathlon, sponsored by DOE and administered by NREL, will educate consumers about solar energy and energy-efficient products and also guide the next generation of researchers, architects, engineers, and builders as they prepare to begin their careers.



research develops and refines technologies to meet the builders' specific needs, and also to test performance to find solutions when things don't work the way we thought they would."

Getting to Zero—Buildings that Produce Energy

Compared to the off-grid, energy self-sufficient Earthships of the 1970s, the Solar Patriot house outside of Washington, D.C., is a space station. Many people have built homes that are self-sustaining, but the Solar Patriot house represents the first mass-market house that is connected to a power grid but not dependent on it. The house uses a photovoltaic system to generate electricity, aided by a solar hot-water system and passive solar design, which has been so successful that it has produced enough excess electricity to consistently spin its electric meter backward.



Installation of PV-integrated standing-seam metal roof panels.

Tim Merrigan, NREL project manager for the new DOE initiative for zero-energy homes, says that the Solar Patriot house is just one of the many zero-energy homes that will be tested during the next few years. NREL has awarded contracts to four teams of builders this past year to develop new kinds of designs for homes.

"Most people can't buy a zero-energy home today, but what does exist is a vast amount of knowledge that will make zero-energy homes available to everyone in the future—building technology research as well as long-term field testing of solar hot-water systems and photovoltaic systems," Merrigan said. "All that research exists and this program brings that research together. The Zero Energy Buildings program has very lofty goals, and we're on the brink of meeting those goals."

What if your house were a mini-power plant, your roof shingles were photovoltaic panels, and heat collecting walls heated your home? These technologies already exist today, and are already being used in living laboratories across the nation to hone them for efficient, large-scale use in the marketplace. It may sound futuristic, but building technologies like these are not far away.

A Future of Zero Energy

In a serene neighborhood just outside Washington, D.C., the Solar Patriot house is quietly heralding the next step in the transition to buildings of the future. The house is so efficient that its 6-kW photovoltaic system produced more electricity than the family used during 2-1/2 months in early fall 2001. Also during that time, the house remained fully powered, while the rest of the neighborhood went dark during eight power outages. In addition, the five-bedroom house is not only affordable for its rapidly growing area of the country, but its exterior needs



The "Solar Patriot," in Virginia has a 6-kW PV system, solar water heater, geothermal heat pump, compact fluorescent lighting, high-efficiency appliances, and low-e windows.

no more maintenance than a conventional home. The standing-seam metal roof has a life expectancy of 40-50 years. Maintenance on the solar systems is minimal.